

## Pair

type 2 counterpart. In the duty ratio, we have the full flexibility as we look at a type 3. The same: how do we did for the TL431 connected in parallel with the LEDs we are looking for in the type 2—see with the equivalent circuit in Figure 8.10:

(8.32)

 $(R_3)+1$ 

(8.33)

transfer function:

$$\frac{D(s)}{I_{FB}(s)} = -G_{PWM} \frac{1}{1+s/\omega_{p2}} \quad (8.34)$$

If we now combine expressions given by (8.33) and (8.34), we obtain the complete chain from the compensator input to the duty ratio output:

$$\frac{D(s)}{V_{out}(s)} = -G_0 \frac{(1+\omega_{z2}/s)(1+s/\omega_{z1})(1+s/\omega_{z3})}{(1+s/\omega_{p1})(1+s/\omega_{p2})(1+s/\omega_{p3})} \quad (8.35)$$

In (8.35), we have

$$G_0 = \frac{CTR}{R_{LED}} G_{PWM} \quad (8.36)$$

$$\omega_{z1} = \frac{1}{R_s C_{V_{cc}}} \quad (8.37)$$

$$\omega_{z2} = \frac{1}{R_1 C_1} \quad (8.38)$$

$$\omega_{z3} = \frac{1}{s C_3 (R_{LED} + R_3)} \quad (8.39)$$

$$\omega_{p1} = \frac{1}{(R_d + R_s) C_{V_{cc}}} \quad (8.40)$$

$$\omega_{p2} = 44 \text{ krad/s} \rightarrow 7 \text{ kHz} \quad (8.41)$$

$$\omega_{p3} = \frac{1}{s R_3 C_3} \quad (8.42)$$

The resistor setting the mid-band gain is the LED series resistor. We first start by extracting the magnitude of the compensator gain,  $G(s)$ , as derived in (8.35):

$$|G(f_c)| = \frac{CTR}{R_{LED}} G_{PWM} \frac{\sqrt{1+(f_{z2}/f_c)^2} \sqrt{1+(f_c/f_{z1})^2} \sqrt{1+(f_c/f_{z3})^2}}{\sqrt{1+(f_c/f_{p1})^2} \sqrt{1+(f_c/f_{p2})^2} \sqrt{1+(f_c/f_{p3})^2}} \quad (8.43)$$

From which we can extract the value of the LED resistor:

$$R_{LED} = \frac{CTR}{G} G_{PWM} \frac{\sqrt{1+\left(\frac{f_{z2}}{f_c}\right)^2} \sqrt{1+\left(\frac{f_c}{f_{z1}}\right)^2} \sqrt{1+\left(\frac{f_c}{f_{z3}}\right)^2}}{\sqrt{1+\left(\frac{f_c}{f_{p1}}\right)^2} \sqrt{1+\left(\frac{f_c}{f_{p2}}\right)^2} \sqrt{1+\left(\frac{f_c}{f_{p3}}\right)^2}} \quad (8.44)$$

The definitions to obtain  $C_3$  and  $R_3$  are rather simple to derive. Extract  $R_3$  from (8.42):

$$R_3 = \frac{1}{2\pi f_{p3} C_3} \quad (8.45)$$